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Supporting Academic Resiliency Among Underrepresented Engineering Students: The Impact of University Academic Systems

Mr. Gholam Abbas Sattar-Shamsabadi II, University of Louisville

Mr. Abbas Sattar-Shamsabadi is a Curriculum and Instruction Ph. D. student specializing in Languages, Literacies, Cultures, and Communities (L2C2) at the University of Louisville. Mr. Sattar-Sahamsabadi serves as a graduate research assistant for the J.B. Speed School's Center for Teaching and Learning Engineering. He received his BS and MAT in P.E. and Health from the University of Louisville. His research interests are in CRT and its applications towards K-12 and college-age students' experiences in organized sports and physical activity, as well as belonging in college-aged students.

Dr. Brian Scott Robinson, University of Louisville

Brian Robinson is an Associate Professor with the Department of Engineering Fundamentals at the University of Louisville. His primary research focus is in Engineering Education, with highest interest in first-year (and beyond) engineering retention & the effects of value-expectancy theory on student persistence.

Dr. Thomas Tretter, University of Louisville

Thomas Tretter is professor of science education and director of the Center for Research in Mathematics & Science Teacher Development (CRIMSTED) at the University of Louisville. His scholarship includes collaborative efforts with science and engineering faculty targeting retention of first-year engineering students as well as other engineering education efforts.

Dr. Angela Thompson P.E., University of Louisville

Dr. Angela Thompson is an Associate Professor in the Department of Engineering Fundamentals at the University of Louisville. Dr. Thompson received her PhD in Mechanical Engineering from the University of Louisville. Her research interests are in biomechanics and engineering education, particularly related to first-year students.

Dr. Jessica Buckley

Supporting Academic Resiliency Among Underrepresented Engineering Students: The Impact of University Academic Systems

This full-length Empirical Research Paper reports the protective mechanisms and risk factors that influence academic resiliency among underrepresented engineering students. Academic resiliency, characterized by students' ability to effectively manage stress, overcome challenges, and persist through difficulties in their academic pursuits, is a crucial factor for success in higher education [1], [2], [3], [4]. A need exists to identify and analyze strategies and programs that strengthen and support student abilities to develop academic resiliency.

The study explores support systems and educational practices universities may use to enhance academic resilience. It also identifies some institutional barriers to resilience. Insights from students regarding their perceptions of these efforts are gathered to assess their effectiveness and identify areas for improvement. Notably, this study leveraged the unique situation of the COVID-19 pandemic. Students interviewed for this study began their first year in the fall of 2020 under severe COVID restrictions, which limited university support services and social interactions. The pandemic functioned as a natural stress test of university support systems, exposing students to unique challenges in managing and overcoming stress under constrained conditions. This study poses the following question: What academic protective mechanisms or risk factors, including those arising during COVID restrictions, do underrepresented engineering students highlight as important for supporting or hindering their academic resiliency?

Literature Review and Conceptual Framework

Resilience is the ability to effectively cope with challenges, such as adversity, trauma, tragedy, threats, or significant stressors like family and relationship issues, serious health concerns, or financial and workplace pressures [5]. Research in resilience investigates why some individuals thrive despite challenges while others struggle [6]. Building resilience involves facing difficulties and finding positive coping strategies [7]. The Academic Resilience Model (ARM) (see Figure 1) illustrates how personal and contextual factors influence resilience among higher education students [1]. Rooted in resilience theory, the ARM encompasses key frameworks explaining student retention and dropout dynamics within higher education [8], [9], [10].

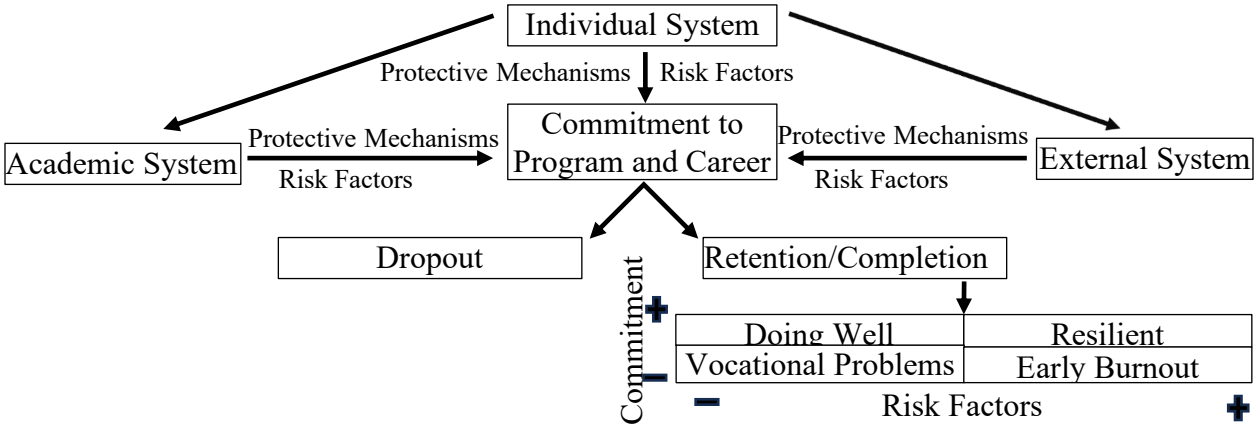

Figure 1. *Academic Resiliency Model (ARM). Adapted from Durso et al. [1]*

The ARM consists of three interconnected systems: the individual, academic, and external systems [1]. Each system includes two sets of factors influencing students' satisfaction and commitment to their programs. The first set comprises protective mechanisms—personal traits like positive thinking, organization, and problem-solving—and protective factors, which are environmental resources such as friend family and friend support or professor availability [1], [11]. For clarity, the term "protective mechanisms" will include both. The second set consists of risk factors, encompassing high stress levels and adverse circumstances that hinder academic progress and contribute to student attrition [1], [12]. Examples include the loss of parents or significant stress levels that lead to health issues. These stressors and adversities hinder successful adjustment in higher education [13], [14]. For this study, risk factors refer to any dynamics negatively impacting academic success [15].

Academic Resiliency Model (ARM) Systems

The individual system encompasses family background, personal characteristics, and previous educational experiences, all of which can be sources of protective mechanisms and risk factors. Family emphasis on education and growth mindsets can be a protective mechanism to counterbalance a risk factor such as socioeconomic disadvantage [1], [16]. The external system, which includes aspects outside the academic sphere, such as work and family responsibilities, similarly affects academic outcomes. Engagement in field-related work can enhance satisfaction and commitment by connecting academic learning to future career aspirations (a protective mechanism), or it can be a source of stress (a risk factor) if it hinders family obligations [17].

The academic system influences students' satisfaction and commitment to their programs and careers [1]. Key protective mechanisms and risk factors include integrating students with peers and professors, structured affinity groups, and the classroom environment. For instance, poor integration can lead to social isolation, reducing students' sense of belonging and overall satisfaction, especially for those from differing backgrounds, such as low-income or older students in traditional settings [18], [19]. Conversely, successful integration fosters support, enabling students to form study groups and benefit from mentorship, which can enhance their commitment to their studies [14].

Academic Resiliency Model (ARM) Outcome Matrix

When students are retained, they can fall into one of four classifications (*Early Burnout*, *Vocational Problems*, *Doing Well*, *Resilient*) based on their degree of satisfaction and commitment to their chosen career path (Y-axis) and the degree of risk factors they experienced during their program (X-axis), as shown in the 2x2 matrix in Figure 1. In the case of our study, because of the COVID-19 pandemic and its negative impact on routine institutional services and heightened stress for students overall, we anticipated that it would magnify the risk factors that influence students' experiences. To identify the protective mechanisms that may have helped students mitigate these risk factors, this study is interested in the success stories of underrepresented students in the engineering program.

Methods

This study is an extension of an NSF-funded study that commenced during the peak of the COVID-19 pandemic in the summer of 2020. Related research and data collection began in 2020 with focus group interviews with small groups of first-year engineering students. For this study, focus group participants from 2020 were invited for follow-up interviews three years later in their academic careers, with 16 responding positively. The 60-90-minute semi-structured retrospective interviews for this study were conducted in spring 2023.

Methodology for the study in this paper involved qualitative thematic analysis of retrospective interview transcripts. These interviews were retrospective because students were asked to reflect and characterize their 3-year experiences in the engineering program. A project researcher and graduate assistant from the university's school of education conducted the interviews to reduce potential unwanted bias or influence from engineering students talking with engineering faculty who are also a part of the project research team. Transcripts from each of the 16 student interviews were thematically coded by a 3-person team (one education researcher, one engineering researcher, and an education doctoral student) using the ARM as a conceptual framework. Student interview responses were coded to align with personal (individual), school (academic), and/or external contexts, and the valences were coded as positive (protective factors) or negative (risk factors). Each interview was first separately coded by each of the three researchers. This was followed by consensus meetings amongst the researchers in which codes were collaboratively compared and discussed, and final coding was unanimously agreed upon.

The results and associated discussion focus on three participants from this 16-student cohort, focusing on the academic system context(s) that are potentially malleable by universities. The selected participants include an African-American female, an African-American male, and a Caucasian female. These students were chosen per the following criteria: a) member of an underrepresented group in engineering, b) a substantial number of codable comments from the interview transcript, and c) cumulative coded transcript comments that are overall representative of comments from the larger, 16-member cohort.

Results

Results are presented for the three participants' interviews beginning with a summary of how each student described themselves in terms of how they perceived their identity and other contextual elements of themselves that they chose to share during the interview. Following this introduction, comments and reflections from each person are shared and organized by four categories that emerged during the coding process: peer interactions, affinity group supports, professors, and cooperative learning experiences (full-time, paid professional work with engineering industry) from the three semesters in which every engineering student at this university participates. These categories represent university-related aspects of their experiences that reflect a relatively consistent pattern of thematic topics addressed across all students.

Aziz

Aziz (all student names are pseudonyms) is a bioengineering major who described herself as "on a five-year plan" for graduation because she needed to retake a calculus class early in her program, and shared her experiences as a female in a male-dominated field. She emphasized the

positives, such as being more easily noticed and forming connections with women in STEM, including her supportive sorority. She expressed that having peers like herself fostered a sense of belonging, stating, “Having people who are like you, I think things like that just make you feel like you belong.” For example, Aziz reflected, “I'm gonna go sit by the one girl in the class because that just feels safe. I think it helps to push myself to make friends in those situations—okay, I'm gonna talk to the one girl because I know she's thinking the same thing I'm thinking.”

Peers: Aziz also noted some of the negatives in her experiences as a female in a male-dominated field. She said, for example, that in class, “I'm gonna not raise my hand 'cause if I get this wrong, that's gonna be super embarrassing for me. It's not that embarrassing. Everybody gets a question wrong, but internally, it is, because the proportion of men to women it just is daunting.” As Aziz was careful to highlight, she recognized that a large part of her perception originates within herself—“internally”—rather than necessarily reflecting comments or judgments of others. Reflecting on her first semester, during the most stringent COVID lockdowns and remote learning, Aziz noted that “making friendships with people in engineering was hard [during COVID].” She also stated that two years later, that first-year absence of building a social network still lingered, commenting, “At this point, it's my third year, people have established their groups, so branching out of your own usual group is hard.”

She commented that not only did COVID severely restrict her ability to meet and make new friends in her first year, but that this also had substantial negative consequences for her. She said, “when you're doing more collaborative work [with peers], that makes a huge difference in my learning.” But because of COVID in her first year, “I didn't have a lot of that collaborative learning, so it put it me on my own. I know the classes that are the most difficult, like the calculus, the chemistry, those ones I barely got through. The semester after, I ended up having to withdraw from Calc 2 because I just didn’t have the foundation from Calc 1.” This is how she found herself on the five-year plan at that point.

Affinity Groups: One bright spot she noted in terms of connecting with peers in her first year was joining the engineering sorority on campus. She shared, “I also had a little bit of a network of people who were off track [behind a course in the foundational calculus sequence], which helped me feel a lot better. Then you talk to people who have gone off track, and you realize how much better it is for them, and that really helped a lot too, to just see other people who were still thriving, but on a five-year plan.” She explained that finding this peer group with a similar academic experience also bolstered her sense of belonging. “I think it's easier to feel like you belong in engineering when you find a group of people that are in your classes that are at the same skill level. Being off track really helped that because then I found kids who had also failed a course and had to deal with — okay, I failed it, I'll move on.”

As reported previously, Aziz found strong positive support for herself when she “joined the engineering sorority, which was super helpful. During COVID [in her first year] it was super helpful to just have friends on campus when you're not able to leave your dorm really. Also, to just have a network of people who have done a lot of different things with their degrees. It was nice to see a lot of different perspectives on what you can do with engineering,” she shared, particularly since this engineering sorority included more senior students and regular interactions with alumnae who would come back to interact with current students. By contrast, she reported

that her experience in the Living Learning Community (LLC; on-campus housing organized by degree or common interests – in this case, reserved explicitly for engineering majors) was not helpful. She said, "The LLC [during first year COVID restrictions] was not a great experience for me. There wasn't anything about it. My suitemates were also engineering majors but that was all we did. We didn't even have virtual meetups, — there was nothing." This COVID-precipitated absence of structured affinity group interactions and socializations underscores how helpful such intentional university structures could be.

Professors: Aziz highlighted that select professors were particularly helpful and supported her success in the engineering program. She said, "I think it helps that there are professors that want you to do well." In addition to professors wanting her to succeed academically, she also emphasized the value of professors who encourage the whole person to complement the academic side of life. "Two professors are very good at making sure you enjoy [your University program]. They want you to, actually, enjoy your time and to, actually, learn. I've had many conversations with the two of them, even about classes I'm not in. They have good insight on…the program." These reflections support the positive impact professors can have – both academically and emotionally – on supporting students as they navigate their program.

Co-op Experience: Aziz did not have as much to say about her co-op experience as others, but she expressed that this aspect of her program was "really useful." She explained that was because, during those experiences, she got "to see what they're doing in the real world. 'Cause sometimes it's hard to conceptualize how your classes are going to apply to real world."

Camila

Camila, a third-year bioengineering major who identifies as Black, noted that there is only one other Black student in her engineering cohort. At the time of the interview, she had just completed her first co-op rotation as a manufacturing engineer, feeling somewhat prepared but acknowledging the challenges of applying classroom knowledge to industry. When describing her experiences in the engineering program, she emphasized that COVID restrictions during her first year significantly hindered her ability to connect with peers. As she said, "starting from freshman year, pretty much all of my classes were online, and now all of my classes are in person. It's been a big shift, but I think it's been nice."

Peers: Camila noted the positive aspects of being in more bioengineering-specific courses with the same small cohort of other bioengineering majors. "There is a sense of camaraderie now that I have only bioengineering classes essentially; that now I'm seeing familiar faces every single time in bioengineering class...It does create a better sense of belonging." She noted that making positive and ongoing connections with peers can be essential to developing a sense of belonging. Camila also stressed the value of connecting with other Black students. When discussing some of her experiences in the National Society of Black Engineers (NSBE), as summarized below in the next section, she highlighted some of the connections she made with other Black engineers outside of her incoming cohort. "We [another member of NSBE] still talk, and if we need something or if we know that there's an opportunity, since we're both Black, if we know there's a Black scholar's opportunity as far as engineering goes, we'll reach out to the other person."

Affinity Groups: Camila described several different affinity groups on campus of which she is a part. One "club that I'm involved in... has been Engineers Without Borders. I'm the secretary for that, and I also handle social media for that as well." She also highlighted that one of the groups she feels most connected to is not an engineering-related group, but instead is her participation in a scholarship program. "Since I'm part of the MLK scholars, a lot of just feeling like I have a place on campus has been by doing things with my cohort or just attending our monthly meetings... Because they always put on activities and just sponsor us getting to know people, and they have been pushing that since the beginning, even with COVID." She also mentioned the value she found in participating in the NSBE: "Then NSBE has been a good way to meet other Black engineers and just have a different kind of network of support. I know in the past they have gone to the Dean's house for a dinner."

Due to COVID, Camila missed out on valuable opportunities, such as structured orientation events that typically introduced students to various campus organizations. She said, "We never did that [first year because of COVID]. I didn't know orientation was a thing in person. That was interesting. I'm glad that they [subsequent cohorts] got to do that, and I know that that was not an option when I started. I was not involved in many student organizations freshman year." Likewise, she described what she has heard from some of her female engineering classmates, "I think some of the girls are part of the professional engineering sorority. I didn't learn about that until I was like halfway through sophomore year, and at that point, I didn't think it was worth it to join, so I just let that go." So, while Camila has found several supportive affinity groups to help her network on campus, she also recognizes that she might have had more opportunities to do so if her first year had not happened during the worst of the COVID restrictions.

Professors: Considering her experiences with professors, Camila thinks, "the professors for the most part, especially the bioengineering department or faculty, I think they're pretty good at listening if you need some sort of support." She also positively reported on some of the teaching techniques used by some professors, "just the way he approached problem solving encouraged me in the way I approach problem solving, and it doesn't seem like as big of a deal. He puts such an emphasis on group work and teamwork that it makes it feel like, even if I can't figure it out myself in the real world, I will have a team of engineers that I can ask for help." However, Camila also recognized that some of her interactions with professors, in general, were limited. She indicated, "I'll be honest, I don't have a close personal connection with any of my professors. They all know my name. If I've had a class with them, I've usually asked for help or gone to an office hours at least once. They recognize me, but I haven't done any research or anything like that with them." She also noted that in her experience, some professors are "really just there for the research, and he has to teach a class in order to maintain a status at the university…" But she further clarified that "most of my poor experiences … have been with classes that aren't part of the actual engineering curriculum."

Co-op Experience: Camila, who had just returned from her first co-op semester before this interview, reported that she found the entire experience rewarding. "Having been able to complete a co-op successfully and done well enough to be asked to come back has given me a little confidence that I at least can do basic engineering level one work and get hired." As she indicated, that experience reaffirmed her abilities and prospects for future field success. Describing her growing sense of belonging in the engineering field, "I think it's been affected by

my co-op most importantly, just making sure that I feel like I am worthy to be working at this engineering firm. 'Cause I don't think that you can sit through nine hours every day, nine and a half hours, whatever, and not feel like you are an engineer." Interestingly, one unintended side effect of spending a semester away from university is that Camila feels less connected to the university engineering program and its people overall.

> I would say that I am at this point [just back from co-op] pretty detached from the engineering school. I think that my answer [to sense of belonging within the university engineering program] has changed since I've been on co-op. I think if I've been asked this probably over the summer, I would say, well, I mean it's my life essentially. I spent all my class time here and, et cetera, but after having gone on co-op, I would say that now I'm just here to finish my degree and move on.

Camila's co-op experience reinforced her fit in engineering but may have weakened her connection to the university engineering program.

Logan

Logan is a mechanical engineering major in his third year of the program. At the time of the interview, he was on his second co-op semester rotation. He identifies as Black and shared that he is very social, including how he likes to learn. He says that talking to people, having others explain something to him, or him explaining something to others solidifies his knowledge.

Peers: Logan described his first-year experience during the COVID restrictions as particularly socially challenging for him,

> COVID really affected me on the social aspect [of my first year] because I'm a really social person and not being able to talk to some of my classmates definitely made it harder. The very first two semesters I was in school, I had no idea who anybody was. It was hard to ask for help from anybody else 'cause I didn't know who they were.

In addition, Logan also shared how he typically uses his peers as a reference point against his academic performance. "Every time I walk into a classroom, I question [my engineering abilities]. Because I'll sit down, take a test, get it back, 40 percent. Look at the rest of class. They all get 70s and above. I'm like, "Ooh, should I be here?" Yeah. The test scores make me question if I should be there." But then he related how he later learned that "the people who talk about their grades are the people who do well, and so the people who don't are the people who score like me, and then I was like, I see more people actually scoring lower than I thought."

Affinity Groups: One of the affinity groups that has had the most impact on Logan has been his participation in the NSBE. "Being a part of that, I guess, helped me a lot. I definitely feel like that NSBE helped because—oh, they're actually the one who paid for me to go to California whenever I went for the engineering conference." While in California, he found his current co-operative learning experience in Hawaii, from where he conducted this interview. Logan also shared another experience he had through NSBE.

> They've definitely helped me in my experiences and being able to put myself out there…they also put me on a business training, like trip to where we got on a bus, and we had three days to make a business idea and actually make a product for it. Then we went down to Texas and had to present an idea in front of investors.

Professors: Logan's social nature also emerged in his comments about his interactions with professors. For example, he shared how he has been able to build comfortable relationships with many faculty members:

> A lot of the faculty, I can talk to normally. A lot of the teachers that I've had, I've talked to 'em after class. Not even about school, sometimes just about random stuff, like sports that's going on or stuff around the city, just anything. Yeah. I feel like that it has impacted me well. 'Cause at that point, the teachers also know who I am or at least that I'm in their class or what my name is. It does help me be seen by them.

He also shared an example of a professor who offered support for a class he was not doing well in. That professor told him, "He even said if I wanted to drop it and still go to the lectures and just learn it, and then when I come back to next semester, I would know most of it already. He said I could do that." Logan expressed appreciation for this professor, considering how the non-positive experience of not doing well in a given class could still be leveraged for future success.

Co-op Experience: Logan expressed strong appreciation for the value of his cooperative learning experiences, which affirmed his belief in wanting to be an engineer and his ability to succeed in the field. He shared, "that helps a lot because the first four semesters that we go back-to-back to back, it is definitely hard going through those classes and like, "Is this even worth it?" Because you don't know what's on the other side or how this will actually implicate into your real-world job or not." Given how he has sometimes struggled with grades in some classes, Logan even offered, "In the classroom, I don't belong in engineering at all, but in the job world I feel like I do belong." Logan expanded further on how the co-op experiences have bolstered his sense of belonging in the engineering field:

> The two internships I've had, I feel like I belong here because I have seen how my work has progressed and actually made an impact. I feel like as a co-op, I've actually done more than a lot of the engineers I work with now because the boss I have, he gave me little stuff at first, and then I would just do it quickly, and then he is like, 'Okay. Here's this.' I do it again. Now I'm just doing what the other employees do on a regular basis.

He also shared his supportive experiences with the professional engineers he has worked with during these co-op experiences. "Every boss and manager I've had so far for my internships have definitely helped 'cause they have always been like, 'If you need anything, just call us."

Discussion

The discussion is organized by the four themes that emerged during the coding process and that were used to structure the presentation of results. These themes capture the prevalence of student comments related to the academic system component of the ARM (Figure 1), highlighting aspects of their university experiences that are potentially malleable by universities. Table 1 summarizes the findings presented in the results section for convenience, followed by a brief discussion of each theme after the table.

Table 1. *Summary of Findings in Results Section*

Theme	Positives	Negatives

Peers	- Calibrating with peers offers confidence - Finding similarities to feel connected	- COVID restrictions for socializing - Some peers can be dismissive
Affinity Groups	- Connection and belonging - Diverse opportunities to find a "fit"	- COVID restrictions did not allow for orientation (lack of awareness)
Professors	- Teaching style effective - Approachable/Supportive - Mentor relationship (academic)	- Some felt non-supportive - Some not perceived as focused on students
Co-op Experience	- Real world application built confidence	- Disconnected with school after

All participants emphasized the value of positive peer interactions as a protective mechanism and the importance of finding peers who share similar experiences, such as being on a five-year plan together or comparing performance to calibrate their own. Some also noted that some peers can feel dismissive, but these resilient students were able to largely set aside any such negative interactions as reflecting on those others rather than being particularly relevant to them. In this way, they were able to leverage positive peer interactions and effectively minimize any negative ones in terms of their own academic trajectory. The COVID restrictions during their first year posed a risk factor for making these peer connections, but ultimately, these students found ways to succeed in their engineering programs despite these barriers.

An essential aspect of the experiences for all participants was finding an affinity group(s) with whom they felt strongly connected and supported. For Aziz, it was an engineering sorority; for Camila, it was several different groups (NSBE, Engineers without Borders, MLK scholars); and for Logan, it was also NSBE. The variety of groups identified by these participants highlights the necessity for the university to create a diverse range of groups that students can engage with – it isn't possible to predict in advance which specific groups any student may discover to be the supportive environment they require to maintain their success.

Additionally, all participants highlighted the importance of professors they could connect with. These connections may be academic-related, such as professors using effective pedagogy to support student learning or being approachable for academic advice. However, it was important for these students to connect with professors beyond academics, seeking emotional support and approachability. Camila contrasted supportive professors with those who were less so, emphasizing the humanizing aspect of engineering professors as being crucial.

Finally, all participants emphasized the significant positive impact of their co-operative learning semesters in industry. They highlighted how these real-world experiences boosted their confidence in becoming successful engineers. At this institution, three co-op semesters are integrated into each four-year engineering program, distributed across fall, spring, and summer semesters, with a full suite of classes each summer when not on co-op so that the engineering program is still doable within four calendar years. The external confidence and affirmation students reported underscore the substantial positive value of these experiences and affirm the time and effort the institution allocates to making them a reality for all engineering students.

Conclusions

This study, framed within the ARM (Figure 1), emphasizes key protective mechanisms and risk factors that influence academic resilience among underrepresented engineering students, centering on how an institution's Academic System can promote academic resiliency and success. The Academic System is crucial in shaping student experiences by offering structured opportunities for peer engagement, affinity group support, professor-student connections, and exposure to real-world engineering experiences. These institutional initiatives can serve as protective mechanisms to help students persist and thrive academically.

Within courses and classroom dynamics, institutions must establish and support a culture that promotes a shared learning journey among engineering students rather than reinforcing perceived differences or competition among students. The COVID-19 pandemic underscored the importance of peer connections for academic resilience. To strengthen this, universities should prioritize structured peer collaborations, encouraging such collaborations within the classroom and out of it. The study also reveals that professor-student relationships are a significant component of student academic resiliency. Professors may not always be aware of how students perceive them. Still, students actively seek connections and mentorship—not only for academic guidance but also for broader personal and professional support. Encouraging faculty to engage with students in ways that humanize the learning experience, whether through informal conversations, mentorship, or student-centered teaching practices, can impact students' academic commitment and persistence.

Outside of classroom dynamics, institutions can also foster supportive structures and resources to bolster academic resilience. A key takeaway from this study is the significance of proactive outreach and structured information fairs about affinity group opportunities on campus, something notably missing for students like Camila due to COVID restrictions. Institutions should implement systematic methods to introduce students to various available affinity groups early in their academic journeys, helping them connect with communities that align with their ambitions. Another key protective mechanism within the Academic System are opportunities for students to benchmark their learning experiences against real-world engineering practice. Structured co-op programs like those at this institution provide students with valuable industry exposure and reinforce their confidence in their engineering abilities. For institutions without formalized co-op programs, alternative strategies—such as department-level initiatives, industry partnerships, or internship support services—can help students gain the necessary experiential learning to strengthen their commitment to the field.

These three engineering students who self-identify within at least one category of underrepresentation in engineering are encouraging success stories, demonstrating commendable resiliency through their program. They shared both some of the positives and some of the challenges they experienced. However, the combination of institutional supports (e.g., affinity group options, co-operative learning semesters, approachable and caring professors) and peer interactions they were able to build, combined with their internal strengths and commitments to the program, have led these students to be on a successful track to graduate from the engineering program and launch a successful career post-degree.

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